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POTENTIAL ENVIRONMENTAL IMPACT OF FUTURE SURFACE MINING OPERATIONS ON THE COCONINO NATIONAL FOREST

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THESIS
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(Funded by Eisenhower Consortium Cooperative Agreement No. 16-34A-CA)

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INTRODUCTION

A geological study of approximately the northern one-third of the Coconino Naticnal Forest has been made for the purpose of characterizing and locating deposits of potential industrial materials. The materials currently in use by various industrial and governmental agencies include: limestone, sandstone, cinders, basalt, sand and gravel and clay (see Table I). A reconnaissance geologic map has been prepared to show the specific location and areal extent of deposits of these materials.

Another purpose of this investigation is a preliminary analysis of probable environmental consequences of surface mining operations.

Three main sources of data have been synthesized during preparation of the reconnaisance geologic map; 1) published geologic maps, 2) black-white and color aerial photographs of the U.S. Forest Service and, 3) field work by means of jeep travel and shoe leather. That portion of Coconino National Forest mapped in this manner is shown in Figure 1. Published geologic maps for this area include: Robinson, 1913; Mintz, 1942; Mears, 1948; Huff and others, 1966; Murray, 1973; Ulrich and Bailey, 1974; Moore and Wolfe, 1974; Kluth, 1974; and Montgomery and others, 1974. All other areas were mapped by aerial photography and field examination, except for a very cursory field examination of the eastern part of the White Horse Hills, 7½' quadrangle, just north of the San Francisco Peaks.

The geologic map has been drawn on a U.S. Forest Service planimetric base (scale 1" = 1 mile) to show the spatial relationships of the rock units mapped during the course of this study.

Additional information gathered during this study consists of location and engineering test data of designated borrow pits under

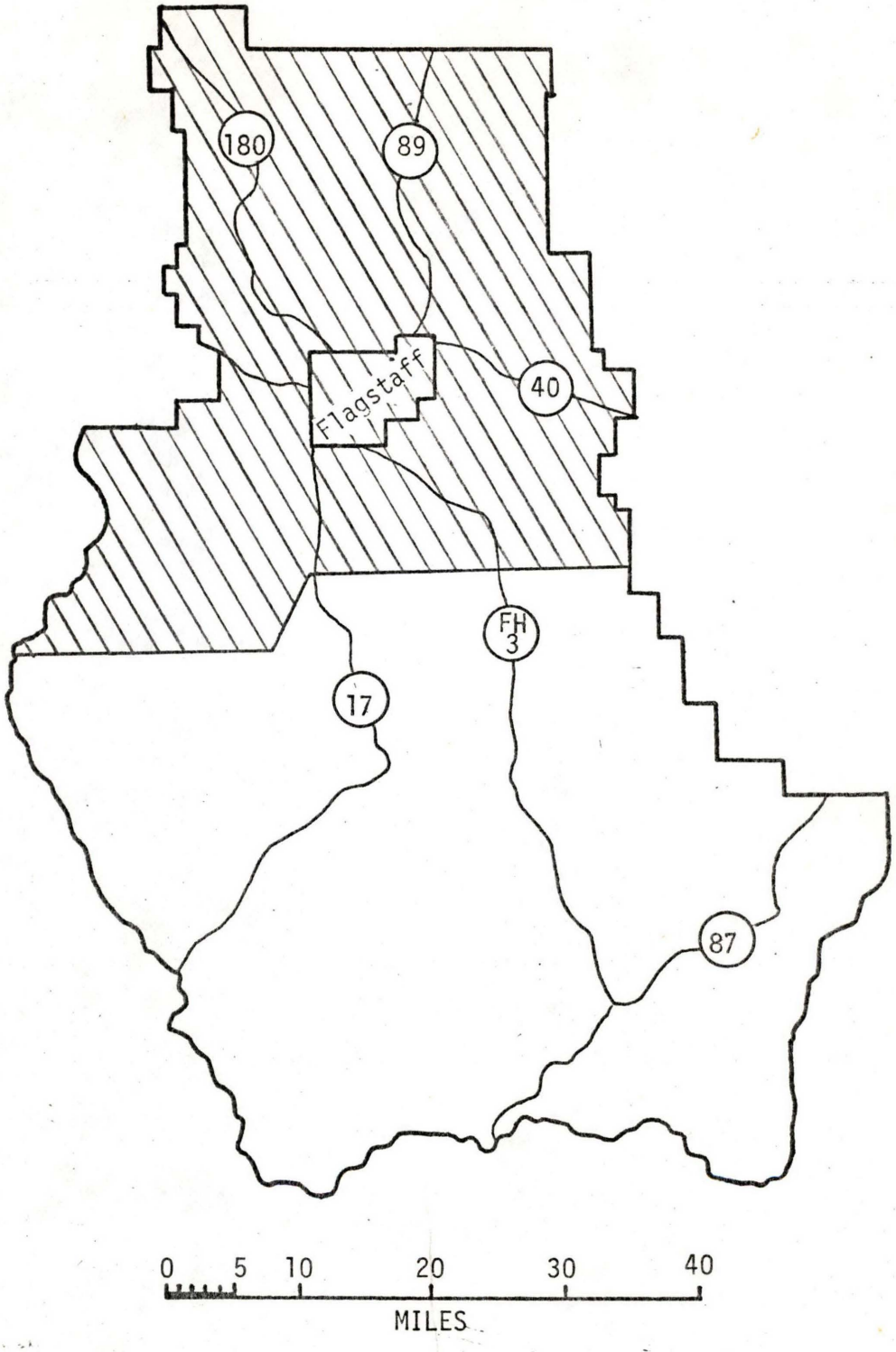

FIG. I INDEX MAP OF COCONINO NATIONAL FOREST. MAPPED AREA SHOWN BY LINED PATTERN.

Table 1. Industrial Uses and Users of Rock Materials from the Coconino National Forest

MATERIAL	USE	USER
Sand and gravel	concrete	building contractors
	fill	road and building contractors
Cinders	road surfacing	U.S.F.S., County
	cinder blocks	block plants
	ornamental	building contractors
Basalt	concrete aggregate	paving contractors
	asphalt aggregate	paving contractors
	road surface and base	U.S.F.S., County, contr.
	building and decorative stone	building contractors
	fill	road contractors
Limestone	cement	cement plants
	concrete aggregate	road and bldg. contr.
	asphalt aggregate	road and bldg. contr.
	road surface and base	U.S.F.S., County, contr.
	fill	road contractors
Sandstone	Flagstone (decorative and building)	building contractors
Clay	stock tank dams and liner	ranchers

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permit to the Arizona Highway Department within the Coconino National Forest. Locations are shown on a U.S. Forest Service planimetric map (scale 1" = 2 miles) of the Coconino National Forest. The locations are numbered and keyed to engineering data sheets included with this report in Appendix B.

DESCRIPTION OF MAPPED ROCK UNITS

The rock units mapped and described in this report possess lithologic characteristics that can be recognized and traced in the field. Rocks exposed in the study area range in age from Cambrian to Holocene, and include sandstone, siltstone, shale, limestone, andesite, basalt, cinders and other pyroclastic material and alluvium. All of these rock units have significance relative to construction materials, water resources or potential geologic hazards. This significance is discussed along with the description of each rock type.

VOLCANIC ROCKS

Age and Rock Type

The volcanic rocks in the northeastern Coconino National Forest have been divided into four age-groups by Moore and others, 1974. These are, from youngest to oldest: Sunset age-group (A.D. 1064, Holocene), Merriam age-group (<100,000 years, Pleistocene), Tappan age-group (0.2 - 0.7 million years, Pleistocene), and Woodhouse age-group (0.8 - 3.0 m.y., Pleistocene and Pliocene). Basalt of Tertiary age, mainly Pliocene, underlies the above mentioned lavas and is abundant in the southern and western portions of the area mapped. These older basalts (Robinson, 1913; Colton, 1936; Cooley, 1962) have been dated by K-Ar

methods between four and ten million years (Damon and others, 1974; McKee and Anderson, 1971; McKee and McKee, 1972).

Basaltic or andesitic lava flows which were erupted from cinder cones or lava cones, cover most of the area. However, volcanic rocks of intermediate to silicic composition occur in isolated areas. Kendrick Peak, Slate Mtn., White Horse Hills, Hochderffer Hills, Sugarloaf Peak, O'Leary Peak, Mt. Elden, Woody Mtn., and the San Francisco Peaks all contain volcanic rocks described as andesites, rhyolites, rhyodacites, dacite or latite (Robinson, 1913; Moore and others, 1974; Kluth, 1974; Murray, 1973; Sheridan and Updike, 1974).

The accompanying geologic map has been prepared using these previously defined rock units as a basis. The San Francisco Peaks and Kendrick Peak have been mapped as "undifferentiated" because these areas are: 1) in the process of being mapped in detail by other individuals (San Francisco Peaks, R. F. Holm; Kendrick Peak, R. B. Moore), 2) relatively difficult to map due to their inaccessibility and 3) under a general policy against development of the San Francisco Peak area. The term "andesite" is used to include several igneous rock types of intermediate composition. Rocks of intermediate to silicic composition, dacites, rhyodacites and rhyolites, that occur in the isolated areas mentioned above have been assigned to age-groups based on radiometric K-Ar ages (e.g. Damon and others, 1974; McKee and others, 1974).

In the southern and western parts of the geologic map, the basalts have been assigned a Tertiary (Pliocene) age on the basis of the above mentioned K-Ar dating. West of the San Francisco Peaks, basalt and cinders have been assigned to the Woodhouse age-group because it appears that lava flows have been deflected by, therefore are younger than

volcanoes dated by McKee and others (1974) as Woodhouse age. In the northern part, mapping by Ulrich and Bailey (1974) and Moore and Wolfe (1974) has been extended to the south and west. Saddle Mtn. has been assigned to Merriam age-group for the following reasons. In Walker Lake, a few miles south of Saddle Mtn., small black cinders overlie pollen-bearing lake sediments thought to be about 30,000 years old (R. Hevley, personal communication). As Saddle Mtn. is the closest, most plausible source of small black cinders, its age is thus inferred to be less than 30,000 years.

Lava Flows and Dikes

For the most part, basalt and andesite occur as lava flows which are typically 10 to 50 feet thick but attain thicknesses of 100 to 600 feet when several flows overlie one another. However, basalt as dikes, is commonly exposed in steep canyon walls, such as Oak Creek Canyon and Sycamore Canyon, and in eroded cinder cones, typically of Tertiary or Woodhouse age. Dikes are generally about four to twenty feet wide and consist of massive basalt. In some eroded cinder cones, the dikes are thin, about one to two feet, and consist of little more than welded spatter.

Cinders

Vents for volcanic rocks may be marked by dikes but are more commonly seen as cinder cones. The areas mapped as cinders include cinder cones of diverse character (see Appendix A). This diversity is due generally to 1) size and size-range of the cinders, 2) their color, generally red or black, 3) the degree of welding and the presence of spatter, 4) the amount of weathering, which is related to the age of the cinders.

The cinders of Sunset Crater, for example, have a very wide range in size, 1 cm. - 1 m., whereas the cinders of Saddle Mtn. are of uniform size, about 1 - 5 cm. Additionally, the cinders of Saddle Mtn. are much smaller than those of SP Crater, which average about 0.5 m. Red is the most common color of cinders. Three notable occurrences of black cinders are in the Saddle Mtn. area, at Wing Mtn., and the blanket of black ash and cinders from the eruption of Sunset Crater. Weathering destroys the sharp, angular shape of the cinders and causes them to become smooth and rounded. Cinders of Sunset and Merriam age generally appear fresher and more angular. Cinders of Woodhouse or Tertiary age are often rounded and are mixed with clay or silt-sized material. Cinders of Tappan age exhibit a range of weathering characteristics.

The degree of welding or presence of spatter is conspicuous in its variation. Within a single cinder cone, the cinders may be loose enough to move under their own weight or welded together so that little short of blasting serves to dislodge them. Whether cinders weld together depends on the extent of cooling as the fragments of magma are airborn. This in turn, depends on the temperature, chemical composition, and gas content of the magma, which can change during the eruption of any one cinder cone. If the gas content is low, or the height to which the cinders are thrown is small, the formation of spatter and the subsequent welding of fragments is favored.

In four instances, because of their scarcity , lithic tuff has been mapped as cinders. Three of these are tuff cones; Wild Bill Hill, Red Mountain, and part of the cone north of Indian Flat. The fourth is a tuff ring at Rattlesnake Crater.

Lava Cones

A notable occurrence of lava cones is also indicated on the geologic map. Although lava cones have been long known in the Snake River lava plains of Idaho, they have not previously been recognized as occurring in the San Francisco volcanic field. Turkey Butte is the largest of the lava cones recognized. The significance of this discovery is that not all conical hills are cinder cones. The slope of lava cones is less steep (10°-13°) than for cinder cones (about 25°).

Pyroclastics

Around Sunset Crater, a large area has been mantled with black, fine-grained cinders from its eruption. This blanket of cinders has been termed "pyroclastics" to distinguish this occurrence from that of a cinder cone. Other deposits of pyroclastics include cinders of Merriam and Tappan age and silicic or rhyolitic ash. Blankets of pyroclastics have variable thickness and great areal extent. Colton (1937) estimates the Sunset Crater pyroclastic blanket covers an area of 100 square miles.

SEDIMENTS AND SEDIMENTARY ROCKS

Alluvium (Quaternary)

Quaternary alluvium includes unconsolidated sediments deposited by running water in stream valleys, on the margins of ephemeral lakes and in alluvial fans. No mechanical analyses of these sediments have been attempted but they generally have a wide range of grain size. No deposits of sand or gravel of uniform grain size were found. Alluvium

in stream valleys and around the shorelines of ephemeral lakes is fine-grained as clay and silt are predominant.

In alluvial fans, which occur on the outer slopes of the San Francisco Peaks, Kendrick Peak, Mt. Elden, Slate Mtn. and Red Mtn., the sediments are more coarse-grained. Cobbles and boulders, of diverse rock types, are commonly found in these deposits, and are embedded in a fine-grained matrix of silt. The Sinagua Formation, described by Updike and Pewe (1970), is typical of these alluvial fans.

Colluvium (Quaternary)

Quaternary colluvium refers to unconsolidated deposits of rock debris which result from downslope movement. Landslides and rock slides are examples of this downslope movement. In the area mapped, colluvium occurs as landslides in the areas of Cedar Ranch and Sycamore Canyon where the Moenkopi and Chinle Formations occur. It is thought that the high clay content of these formations, when water-saturated, is responsible for these massive landslides. The second circumstance in which colluvium occurs is on the downthrown sides of large faults such as the Oak Creek Fault or the Lake Mary graben system. Generally, very large blocks of basalt and other rocks which outcrop in the vicinity are incorporated in these deposits.

Cenozoic Gravel

Gravel deposits of Cenozoic age have been reported in several locations along the rim of Sycamore Canyon (Price, 1950), in the Verde Valley (Mahard, 1949) and along the eastern wall of Oak Creek Canyon from Don Hoel's Cabins to the Schnebly Hill Road (Mears, 1948).

The gravels rest on an erosion surface cut into strata ranging stratigraphically from the Moenkopi down into the Supai Formation, and are usually overlain by Pliocene basalts (Mears, 1948). Price (1950) describes two types of gravels which he designates as Type A and Type B.

Type A gravels consist of angular to subangular clasts of varied composition including Precambrian granite, gneiss and quartzite; chert and limestone from the Kaibab, Redwall and Martin Formations; and sandstone from the Coconino and Toroweap Formations (Mears, 1948). These gravels were derived from outcrops of rocks ranging in age from Precambrian to Permian exposed to the south and southwest. McKee and McKee (1972) have established the age of this gravel in Oak Creek Canyon as between eight to ten million years.

We have mapped two previously unreported occurrences of Type A gravels in the Rattlesnake Burn area (Sec. 29, T19N, R5E) and in the West Fork of Oak Creek (Sec. 9, T19N, R5E). The thickness was not determined in either area because of the poor exposures. In both areas the gravels rest on Kaibab Limestone and are overlain by Tertiary basalt.

Type B gravels are younger than Type A and are composed of well-rounded clasts mainly of quartzite and chert derived from weathering of the Shinarump Conglomerate. They typically include clasts of petrified wood ranging in size from splinters to logs (Price, 1950). Type B gravels occur scattered over outcrops of Moenkopi Formation, where they were either weathered in-place or were washed down from outcrops no longer intact (Price, 1950). Type B gravels were reported by Price

only in the Winter Cabin and Ott Mountain area, and we did not observe them anywhere else in the mapped area.

Chinle Formation (Triassic)

This formation is well exposed in the valley of the Little Colorado River, about ten miles east of the Coconino National Forest. It consists of about 1000 feet of predominantly claystone and clayey sandstone with minor ledge-forming beds of lenticular sandstone and limestone. The basal Shinarump Member is a unit of sandstone to conglomeratic sandstone of variable thickness, ranging from 0 - 100 feet (Wilson, 1974, p. 197 and Evensen, 1958, p. 95). However, within the Coconino National Forest, only remnants of the sandstones and claystones of the Chinle Formation have been observed in the Cedar Ranch (Ulrich and Bailey, 1974) and Anderson Mesa areas.

Petrified wood and leaf impressions are common in the lower part of the Chinle Formation (Ash, 1969), the finest occurrence being in the Petrified Forest National Monument about 25 miles east of Holbrook. Some petrified wood is found in the Cedar Ranch area and may be found wherever the Chinle Formation is exposed.

Moenkopi Formation (Triassic)

This rock unit consists of predominantly red to brown fine-grained sand and mudstone in the area of the Coconino National Forest where it ranges in thickness from 0 to about 500 feet. Within the mapped area, the formation occurs as scattered outliers and remnants that have survived a general erosional stripping of Mesozoic strata from the southern border of the Colorado Plateau (McKee, 1954, p. 29). The

most extensive exposures are found in the Sycamore Canyon, Cedar Ranch, Flagstaff and Anderson Mesa areas where the Moenkopi has been preserved as basalt-capped mesas. Reports of the Moenkopi Formation in the logs of water wells indicate that it may be widespread in the subsurface beneath the volcanic rocks of the San Francisco volcanic field.

Natural exposures generally form unstable slopes which result in landslides and similar colluvial processes as in the Cedar Ranch area.

Kaibab Limestone (Permian)

This rock unit is present throughout the northern Coconino National Forest where it is exposed as a stripped surface generally south of I 40 and Highway 66 and between Oak Creek Canyon and Sycamore Canyon, along the Mogollon Rim. Elsewhere it is covered by younger rocks such as the Triassic Moenkopi Formation and Cenozoic volcanic rocks. In areas of exposure, the Kaibab forms a level to undulating surface, interrupted frequently by steep-walled canyons formed by incised stream courses.

The dominant lithology is limestone in beds ranging from a few inches to four feet and contains dolomite, chert, and sandstone in varying proportions. The thickness varies from 700 feet along the western boundary in Sycamore and Oak Creek Canyons to 400 feet along the eastern boundary of the National Forest at Grand Falls (McKee, 1938). At the head of Oak Creek Canyon, erosion has reduced its thickness to 75 feet (Murray, 1973).

The limestone is relatively impure because of included chert, clay and sand, therefore it has been used only rarely for industrial purposes,

as aggregate where better material is unavailable and as borrow material for fill projects. It is typically fossiliferous, containing brachiopods, sponges, mollusks and trilobites, which are tempting to fossil collectors.

The limestone is cavernous, especially along fault systems and joints and frequently is the source of springs along the walls of canyons eroded into it. Sinkholes are commonly developed in areas of Kaibab exposure and sometimes penetrate through overlying Moenkopi and/or basalt. Undercut cliffs of Kaibab commonly shelter prehistoric cliff dwellings (e.g. in Walnut Canyon).

Toroweap Formation (Permian)

This formation is recognized in the mapped area only in Sycamore Canyon where it consists of about 300 feet of pale orange, "gnarly bedded" sandstone (McKee, 1938, p. 19). Twenty miles to the east in Oak Creek Canyon, the same stratigraphic interval (i.e. between the Kaibab Formation and the Coconino Sandstone) is occupied by 420 feet of white cross-bedded sandstone (McKee, 1938, p. 19) which is "similar to the Coconino Sandstone in lithology and crossbedding" (Rawson and Turner, 1974, p. 166). The same relation is found in Walnut Canyon and in the valley of the Little Colorado River to the east and northeast of the Coconino National Forest. For this reason, we have mapped the cross-bedded sandstone beneath the Kaibab Formation as Coconino Sandstone.

Coconino Sandstone (Permian)

This rock unit is exposed only in the deepest canyons (e.g. Walnut, Oak Creek and Sycamore Canyons) north of the Mogollon Rim, and in uplifted areas of Mount Elden, Slate Mountain and White Horse Hills. It consists of nearly pure quartz sand cemented with calcite or silica forming a hard, resistant sandstone. It is markedly cross-bedded with well-defined beds ranging in thickness from two to six inches. The color varies from white to buff on fresh fractures, but is often coated with black desert varnish (iron and manganese oxides) in weathered exposures. Measured thicknesses within the area of this report range from 726 feet in Oak Creek Canyon (= Coconino plus Toroweap of Mears, 1948, p. 8 and 9) to about 900 feet in the Woody Mountain #1 water well about one mile northeast of Woody Mountain in Sec. 35, T21N, R6E (Montgomery, personal communication).

The Coconino Sandstone is profitably quarried in the Ashfork area and sold is flagstone. It is in demand in the construction industry for decorative stone facing for fireplaces and buildings and as paving stones for patios and walkways.

Exposures along the Mogollon Rim are relatively accessible at several places and could come under public demand in the future.

The Coconino Sandstone is well known to fossil collectors because of commonly well-preserved reptile trackways on bedding planes.

In the subsurface, the Coconino Sandstone serves as a reservoir for groundwater production in areas of favorable structure and reservoir characteristics. The City of Flagstaff produces water from this formation in the Woody Mountain and Lake Mary well fields. We have mapped several other areas in the Coconino National Forest, which are located on structural

features that are comparable to the Woody Mountain and Lake Mary structures and appear to have potential for groundwater production.

Supai Formation (Pennsylvanian and Permian)

This rock unit is exposed in the area of this report in the lower slopes of Sycamore and Oak Creek Canyons where it was determined to be 1535 feet thick (Mears, 1948, p. 7). It forms the famous "red rocks" of Oak Creek in the Sedona area and for several miles in both directions along the Mogollon Rim. The formation is also exposed at Mount Elden, White Horse Hills, and Slate Mountain.

The lithology varies from massive sandstones in the upper parts to thinner beds of sandstone, shale and limestone in the lower parts. The upper part forms cliffs and steep slopes and the shales in the lower part weather into gentle slopes.

Rocks of the Supai Formation have been used locally for building stones and for borrow. It is usually unfossiliferous, although the tracks of reptiles do occur in some areas and have been observed along the South Kaibab Trail in the Grand Canyon.

Redwall Limestone (Mississippian).

This rock unit is rarely seen within the mapped area, being exposed only at Mount Elden, White Horse Hills and Slate Mountain. It is predominantly light gray, coarse-grained, consists of limestone and dolomite, and is exceptionally free of sand and clay (McKee, 1969, p. 4). The thickness varies from 225 feet at Slate Mountain to 185 feet at Mount Elden (McKee, 1969, p. 3), the easternmost exposure in the mapped area.

The Redwall Limestone is cavernous, especially along fault zones, therefore has potential for groundwater production. The City of Sedona produces water from wells in the Redwall now and the City of Flagstaff is planning to test this water potential in the future.

The only current industrial use of this limestone is for cement manufacture at Clarkdale, outside the boundary of the Coconino National Forest. It is the only source of limestone with the purity required for this purpose therefore could have future demand.

Martin Group (Devonian)

This rock unit is exposed only at Slate Mountain and Mount Elden. It consists of dolomite, sandy dolomite and sandstone, varying in thickness from about 100 feet at Slate Mountain to 370 feet in the subsurface at the Roy Owen, Diablo Amarillo #1 Well in Sec. 12, T20N, R11E about seven miles east of the Coconino National Forest boundary. It has been measured as 152+ feet at Mount Elden (Beus, 1973, p. 18).

No industrial use has been made of this rock unit to our knowledge, although it has produced oil and gas and is considered a potential source for future oil production (Conley, 1974, p. 405).

Tapeats Sandstone (Cambrian)

This is the oldest rock unit within the mapped area and is exposed only at Slate Mountain where its thickness has not been determined because of structural complexity.

It is typically a medium to coarse-grained flat- to cross-bedded, brown sandstone. No industrial use has been made of this rock unit.

FACTORS THAT AFFECT THE CHARACTERISTICS OF ROCKS AND SEDIMENTARY DEPOSITS

SEDIMENTS

The sediments that have been mapped which constitute minable or potentially minable industrial materials are primarily alluvium. Several sand and gravel pits operated by private individuals or governmental agencies are in alluvium (e.g. SW ¼, Sec. 17, T23N, R6E).

The characteristics of alluvium, such as size, shape and rock type of the fragments as well as the continuity or lateral extent, are extremely variable. For example, the Sinagua Formation described by Updike and Pewe (1970) contains fragments ranging from clay-sized to boulders larger than three meters. The rock types represented include all rock types of the San Francisco Peaks, such as andesite, dacite and rhyolite, as well as fragments of all underlying Paleozoic formations. The sand and pebble-sized sediments are more rounded than those of larger size. North of Slate Mtn. an alluvial fan covers nearly a square mile and has markedly different characteristics. Close to Slate Mtn. it contains angular to subangular, pebble to boulder sized fragments of Paleozoic sedimentary rocks and rhyolite that are surrounded by a silty and sandy matrix. About one-half mile farther north, the abundance of fragments decreases from nearly 100% close to the mountain to about 10%. A third type of alluvial fan occurs on the east side of cinder cones of Tappan age northeast of Saddle Mtn. Here, the alluvium consists of small black cinders set in a silty, yellow-ochre matrix. A few small bombs or fragments of bombs are present. All three of these types

of alluvium contrast with that found in stream channels surrounded by flat-lying Kaibab Limestone. In these alluvial channels, black silt and clay can be found interbedded with discontinuous layers of chert pebbles derived from the Kaibab.

In summary, the use of alluvium as a source of sand and gravel or as aggregate depends on the specific characteristics of alluvium in a particular location. As the foregoing discussion indicates, the factor that most determines the characteristics of the deposit depend on the rock types up-slope. Therefore, moving a potential site down or across slope in an alluvial fan can make considerable differences in the characteristics of a deposit and its potential use.

SEDIMENTARY ROCKS

As mentioned previously in the description of the individual units, these rocks have been used for aggregate and building stone. As ancient sedimentary rocks have both lateral and vertical uniformity, it is much easier to reliably evaluate a potential quarry site. For example, the characteristics of the Kaibab Formation are uniform throughout the Flagstaff area except along the Pumphouse Wash where abundant chert nodules occur in the Beta member of the Kaibab (McKee, 1938). The Coconino Sandstone is everywhere a medium-grained, cross-bedded quartz sandstone.

VOLCANIC ROCKS

Basalt

Volcanic rocks, mainly basalt, have been crushed and used as aggregate. Of several quarrying operations in the past, one in current

operation by the Highway Department, State of Arizona is northwest of Fort Tuthill. This is a particularly interesting operation because a highway department geologist noted that the selection of this deposit was due to its fine-grained, brittle nature. This lava flow has been described by Murray (1973) as a "basaltic andesite". Basaltic andesites are different from basalts in that they contain a little more SiO_2 (about 4%) and a little less FeO and MgO (about 2%). The effect of these compositional differences is that basaltic andesites are finer grained, and in this particular case, even contains glass. It would seem that basaltic andesites may yield better aggregate than basalt.

Cinders

The demand for and usefulness of cinders makes cinder deposits a very important resource that is abundant in the Coconino National Forest. According to calculations listed in Appendix A, there are approximately 5×10^9 cubic yards of cinders in the Flagstaff District of the Coconino National Forest alone. However, the volume of usable or minable cinders is much less than this figure. This results from our observations that characteristics of cinders vary significantly from one cone to the next but also within the same deposit. The variations of size, size-range, color, degree of welding and weathering have been described briefly. There are a number of observations which suggest systematic relationships between several of these characteristics.

In a number of cinder pits, the lowermost (stratigraphically) cinders in the deposit contain abundant fragments of Paleozoic sedimentary rock; particularly Kaibab Limestone and Coconino Sandstone. The proportion of these fragments of sedimentary rock relative to cinders

decreases gradually in overlying layers of cinders. Exposures in the small cinder cone in Sec. 11, T20N, R7E illustrate this characteristic very well.

In several cinder pits, it was observed that small, black cinders were generally overlain by larger, red cinders. The Riordan Cinder pit located in Sec. 15, T21N, R6E and the cinder pit in Sec. 17, T23N, R6E are both examples of this feature.

Another relationship is that bombs and spatter, which often occur together, generally overlie the red cinders. This relationship can be seen in almost any cinder cone we observed. When the bombs and spatter become essentially 100% of the deposit, ledges of bombs and spatter that have been welded together commonly occur. Examples of this are found in the Slate Mtn. cinder pit; Sec. 6, T24N, R6E; and the large cinder cone north of there in Sec. 36, T25N, R5E.

The occurrence of dikes in cinder cones is such that they cross-cut zones of spatter or welded spatter. Often these dikes can be seen to feed a lava flow that flowed down the side of the cinder cone. Examples of these features can be seen in the northwestern part of the Horseshoe Hills in Sec. 30, T24N, R6E.

PROCESSES OF CINDER CONE FORMATION

Each of these features is related to processes that occur during the formation of a cinder cone. These characteristics are therefore related to fundamental properties of magma; such as 1) viscoscity of the magma, 2) amount of gas in the magma, 3) temperature of the magma and 4) the rate of magma eruption.

As illustrative of how these factors can affect the character of an eruption, consider the difference between a lava cone, (no cinders), and a cinder cone. Cinders are not produced when gas can easily escape from the magma or when the gas content is small. The ease of gas escape is enhanced by higher temperature and/or lower viscosity of the magma.

By inference then, cinder cones occur because magma has gas in it which escapes as eruption occurs. It is generally thought that cinder cones represent a single eruptive event (MacDonald, 1972). As lava flows seem to occur during or after formation of a cinder cone, the gas content of the magma apparently decreases. The characteristics of cinder cones discussed above are systematically related to the decrease of gas content.

It is thought that when a fracture develops, which later serves as the conduit for magma, the accompanying reduction of pressure causes gas to exsolve from the magma. The subsequent increase of volume drives the magma up the conduit. When gas bubbles rise in the magma, the nature of the initial eruption is a blast of gas that contains abundant fragments of wall rock ripped from the conduit in transit. As the proportion of liquid magma to gas increases, the deposit of material around the vent contains fewer fragments of wall rock and more cinders. This accounts for the first characteristics noted above. Rittmann (1962) terms the rock containing abundant fragments of wall rock (in this case, Paleozoic sedimentary rocks) and cinders a "vent-opening breccia".

A further decrease in gas content of the magma is also responsible for the transition from cinders to spatter and bombs and from spatter and bombs to dikes and lava flows. Whether the bombs and spatter weld

together depends on the length of time these fragments are air-borne; the shorter this time, the greater the likelihood that they will still be soft and weld together. As the heights to which the fragments are thrown depends on gas content of the magma, the decreasing gas content indirectly favors welding of bombs and spatter. Welding also depends to some extent on temperature of the magma although it is of secondary importance.

The size, and hence size-range, of cinders is thought to depend on the amount of gas in a magma and the ease with which it escapes. The smaller the gas content, the larger the cinders or spatter; the easier the gas escapes, the larger the cinders or spatter. Furthermore, according to this idea, Sunset Crater magma has a smaller gas content than that resulting in Saddle Mtn. Variation of either of these factors can cause changes in size characteristics of a given deposit.

Except to state the obvious, that red cinders represent eruption under oxidizing conditions, it is difficult to understand precisely why black cinders occur beneath red cinders. One possibility, again related to a large gas content and also to a high rate of eruption, is that during the time of eruption of the black cinders, the temperature was so high and the rate of eruption was so rapid that essentially anoxic conditions were obtained. Later, when the rate of magma eruption decreased, the cinders were subjected to an oxidizing environment. Again, this may also be related to a decrease of gas content.

STRUCTURAL GEOLOGY

REGIONAL SETTING

The portion of the Coconino National Forest discussed in this report is located on the southwestern part of the Colorado Plateau physiographic province. This province is separated from the Basin and Range province by the Mogollon Rim which occurs in the southwestern part of the area mapped. The Colorado Plateau is composed primarily of horizontal or gently dipping strata of Paleozoic and Mesozoic sedimentary rocks. In the northern one-third of the Coconino National Forest, these rocks are overlain by basaltic and andesitic lava flows of Late Tertiary and Quaternary age. Locally these rocks are displaced by faulting or by folding along monoclinal axes. The age of most of this structural adjustment is Pliocene or Pleistocene as most faults cut volcanic rock of these ages. There are few faults that are demonstrably older than Pliocene. Furthermore, these faults and folds are oriented parallel to directions of regional jointing, which are: 1) north-south, 2) east-west, 3) northwest-southeast and 4) northeast-southwest (McLain, 1965; Murray, 1973).

FAULTS AND FAULT SYSTEMS

Description

The rocks of the Coconino National Forest have been broken by several types of faults and fault systems. These include: 1) simple faults, 2) fault systems consisting of several faults, 3) simple grabens that are bounded by two faults and 4) graben systems that consist of several graben faults. The largest fault in the mapped area is the Oak Creek fault that trends generally north-south and has an

average displacement of 500 feet, west side up (Mears, 1948). The Oak Creek fault is mostly a simple fault although between Woody Mtn. and the head of Oak Creek Canyon it consists of two parallel faults. There are several other simple faults in the mapped region, but few of them are north-south; most are northwest trending. The displacement along these northwest faults varies along their trace, reaching a maximum of 150 feet in many cases. Generally, the sense of displacement of these faults is northeast side up. However, in the area between Interstate 17 and the Oak Creek fault, the displacement is northeast side down. One feature of the larger single faults (displacement of 200+ feet) is the phenomenon of contrary bending. This was first observed along the Oak Creek Fault (Mears, 1948), but we have found two other occurrences. One is along the north-south fault west of Walnut Canyon National Monument, and the other is along the northwest trending fault at Mortgage Spring.

The orientation of simple grabens is also generally north-south or northwest-southeast. The displacement of the graben faults ranges from 10 to 250 feet. The most conspicuous simple grabens are the grabens occupied by Interstate 17 south of Flagstaff (north-south) and the graben occupied by Casner Cabin Draw and Howard Pocket between Oak Creek Canyon and Sycamore Canyon.

Fault systems occur along the trend of monoclinal folds. The faults north of Cedar Ranch are examples of this. The Lake Mary graben system is the most outstanding graben system we have mapped. Its displacement and change of orientation is accomplished by displacements along as many as seven faults, having displacements as large as 300 feet.

All of the faults mapped are thought to be vertical or high angle faults. Mears (1948) argued that the Oak Creek fault was a high angle

dip-slip fault due to the sharp junction of linear sections. Geophysical studies of the Lake Mary graben system indicate that the northeast bounding fault along Anderson Mesa is a high angle fault (E. L. Montgomery, personal communication).

Significance

Economically, large faults, grabens and graben systems are important because they affect the occurrence of producible groundwater in the Flagstaff area. Apparently, the transmissibility and permeability of aquifers are enhanced by the fracturing of the Paleozoic rocks along these fault zones. The most notable water wells that have been developed in these fault zones are the well fields of the City of Flagstaff at Woody Mountain and Lake Mary. These wells produce primarily from the Coconino Sandstone at depths ranging from 1100 to 1300 feet (E. L. Montgomery, R. H. DeWitt, personal communication).

MONOCLINES

Evidence of two monoclines exist along the northern boundary of Coconino National Forest. These are the Mesa Butte - Additional Hill - Coconino Point Monocline (Shoemaker and others, 1974; Barnes, 1974) and the Black Point Monocline at Wupatki National Monument.

SUMMARY AND CONCLUSIONS

There are two general categories into which the conclusions and summary statements of this investigation fall. The first refers to methods of investigation to ascertain the characteristics of a deposit

of alluvium or cinders so that the deposit can be profitably and efficiently used. The second refers to the potential environmental impact of future surface mining operations. There are three aspects to be considered under this second area. These are: 1) visual or esthetic effects of having scarred, treeless landscape in public view, 2) effects due to enhancement of geologic processes of aggradation and degradation, 3) effects related to the U.S. Antiquities Act.

EVALUATION OF ALLUVIUM AND CINDERS

The field studies we have executed have resulted in definition of several aspects of these deposits pertinent to engineering and mining considerations, but separate from them. From previous discussions, the description of deposits mapped and the tabulations of Appendix A, it is obvious that the characteristics of both types of deposits have significant variation. For this reason, we recommend that a geologist make surveys of potential deposits for industrial use.

In the case of an alluvial deposit, the deposit ought to be examined in regard to its lateral and vertical variations. When the deposit has been dissected by erosion, the evaluation can be accomplished quickly and easily. Otherwise, a drilling program ought to be designed and executed. At the same time samples of the deposit should be collected for testing of engineering properties.

Previous discussions have developed the basis for evaluation of cinder cones. According to the geologic processes, cinders result when the magma has a lot of gas relative to its liquid portion. This suggests that by simply mapping the size of a cinder cone and the extent of lava flows erupted from that cone, one should select large cinder cones with

small lava flows. Direct field observation combined with our understanding of processes that operate during formation of a cinder cone suggests the following recommendations:

1. Avoid cinder cones that are cut by dikes near the summit or those having lava flows that have flowed from the summit and down the side.
2. Of two possible cinder cones, choose the one having the least amount of welded spatter, spatter or bombs near its summit.
3. Avoid cinder cones of Tertiary (Pliocene) age in favor of those of Woodhouse, Tappan or Merriam age. Older cinders are more weathered and therefore have different properties.
4. Design and execute a drilling program to determine the characteristics of the deposit at depth. This deals with the problem that often cinder cones are different on the inside than their exterior suggests.

POTENTIAL ENVIRONMENTAL IMPACT

Of the three aspects of potential environmental impact of future surface mining operations; our expertise is mainly directed toward the effects on surface geological processes but some implications refer to the esthetic environmental and antiquities aspects.

It would seem that to minimize visual effects to our environment, one must 1) conduct surface mining operations in areas that are shielded from public view, 2) begin mining a cinder cone with the aim of taking all of it, thus leveling the land surface. In conversations with people in the headquarters of the Coconino National Forest, we found that they

are ahead of us in this thinking and offer here some further suggestions. One area that is not conspicuous to travelers is a 20-25 square mile area east of Saddle Mtn. and north of the San Francisco Peaks that contains cinders of varying characteristics and alluvial fans composed of those eroded cinders. It seems that a major contributor to surface mining operations is the Arizona State Highway Department. As can be seen from Appendix B , most of their surface mining operations are picked for convenience. Two such surface operations; cinder pit, Sec. 11, T20N, R7E, and Kaibab Limestone, Sec. 1, T18N, R6E; that have been abandoned, have been used by people living nearby as garbage dumps for everything from food refuse to car bodies. Ironically, another quarry for Kaibab Limestone was then opened about six miles north (Sec. 6, T19N, R7E) of the later pit, crushed and hauled south of Munds Park for construction of Interstate 17. The U.S. Forest Service should continue efforts to minimize the number of surface mining operations near centers of population. In regard to selecting a cinder cone to be completely mined; earlier recommendations as to selection of the deposit should be exercised.

In regard to the geologic affects of surface mining operations, the main threat involves substantially altering the existing slope stability conditions. Slope stability problems do not appear to be great in mining of cinders unless the cone is associated with a large alluvial fan. An alluvial fan in the previously mentioned area east of Saddle Mtn. would have to be excavated with care. If material was removed so as to increase the slope gradient in that area, significant increase of erosion of the cinder cones may result.

The U.S. Antiquities Act is an effort to preserve artifacts of American heritage. In this regard, one could think of the eruption of Sunset Crater as substantially affecting this heritage and therefore worthy of preservation. On this basis, then, exclusion of mining operations from the pyroclastic blanket of Sunset cinders and ash may be warranted. Additionally, the occurrance of unique fossil localities may be significant enough to preserve them from total destruction.

ACKNOWLEDGEMENTS

We wish to acknowledge the contributions made by several individuals to the completion of this project. Administrative assistance and technical advice has been generously forthcoming from U.S. Forest Service personnel: David Herrick, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado; Don Freeman, Oliver Bacus, George Rice, Sandra Ernst of the Coconino National Forest Supervisor's office, Flagstaff; Roger Baker and his associates in the Flagstaff District, Coconino National Forest, Arizona.

Engineering and locality data for borrow pits was kindly provided by Elliott Gappinger of the Arizona Highway Department - Materials Division, Phoenix, and Arturo Martinez assisted in tabulation of the data. Consultation with Errol Montgomery about water well data, with Sandra McDonald on her cinder cone research, and with Richard Hevly and Bill McCormick on palynological data, has been very helpful and is greatly appreciated. Denny Bridges aided the aerial reconnaissance as pilot and the typing of this report was done by Connie New.

We are grateful to the Eisenhower Consortium and the U.S. Forest Service for the financial and logistical support that has made this

project possible. Finally, we would like to thank the two little kids at East Pocket Lookout for returning Ray Eastwood's Brunton compass and rock hammer.

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APPENDIX A

INVENTORY OF CINDERS AND CINDER CONES OF THE FLAGSTAFF DISTRICT OF THE COCONINO NATIONAL FOREST

The following information describes briefly the occurrence of cinders, as cinder cones and fissure eruptions in the Flagstaff District of Coconino National Forest. There is an estimated 4911.57 million cubic yards of cinders in this District. The probable uncertainty of the calculations is about 10% (relative error). This error is due to the departure of actual shape of the cinder deposits from the regular geometric figures employed for the calculations. Whenever possible, regular geometric figures of cones, cylinders, and prisms were used. Where necessary, fractions of each shape or combination of shapes were used and asymmetry of the deposit or irregularities of the surface onto which it was erupted was accounted for. The probable relative error of 10% is as estimated by recalculation of a particular deposit's volume by different methods and remeasurement. The volume of cinders removed from these deposits, as evidenced by cinder pits, was not taken into consideration as most are insignificant compared to the volume of the cone where they are located. The reader is referred to the section on characteristics of cinder deposits for inferences as to use.

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
Red Mtn.	Sec. 29, T25N, R5E 35° 31' 30" N 111° 52' 30" W	Lava capped tuff cone	532
unnamed	Southern boundary of Sec. 29, T25N R5E 35° 30' 48" N 111° 52' 43" W	Lava capped cinders	6.3
unnamed	Sec. 26, T25N, R5E 35° 30' 58" N 111° 49' 36" W	Unsuited for use due to massive beds of welded spatter 25-60 feet thick on its southwest side.	2.8
unnamed	Sec. 35, T25N, R5E 35° 30' 40" N 111° 49' 28" W	Welded spatter and bombs on top, cinder pit on southwest side contains black cinders, bombs and blocks	2.0
unnamed	Sec. 35, T25N, R5E 35° 30' 25" N 111° 49' 21" W	Top is littered with bombs and a road cut shows mixture of bombs and cinders	0.8
unnamed	Sec. 35, T25N, R5E 35° 30' 15" N 111° 49" 18" W	Road cut shows medium sized bombs mixed with cinders	0.1
unnamed	Sec. 36, T25N, R5E 35° 30' 35" N 111° 49' 07" W	Top is littered with small bombs	0.1
unnamed	Sec. 36, T25N, R5E 35° 30' 03" N 111° 48' 50" W	Cinders, two dikes exposed at the top, one trends northeast, the other east.	0.4
Colton #201	Sec. 30, T25N, R6E 35° 31' 12" N 111° 48' 02" W	Red cinders, bombs and welded spatter; very inaccessible	9.9
Colton #248	Sec. 36, T25N, R5E 35° 30' 35" N 111° 48' 28" W	Red cinders and large bombs, on west side 15-25 foot ledges of wedged spatter crop out	56.9

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
Missouri Bill Hill, Colton #213	Sec. 26, T25N, R6E 35° 31' 20" N 111° 42' 52" W	Cinders and contains local welded spatter	148.3
Colton #162	Sec. 16, T25N, R7E 35° 32' 35" N 111° 39' 17" W	Cinders and contains local welded spatter Only south half is in Coconino National Forest.	183.5
Crater 160	Sec. 22, T25N, R7E 35° 32' 35" N 111° 38' 11" W	Interbedded cinders and massive layers of welded spatter. Less than ½ volume is actually cinders. Only south ½ is in Coconino National Forest.	448.9
Red Hill Colton #159	Sec. 23, 24, T25N R7E, 35° 32' 21" N, 111° 32' 27" W	Interbedded red cinders and units of welded spatter. Only south ½ is in Coconino National Forest	199.3
Colton #100	Sec. 25, T25N, R7E 35° 31' 24" N 111° 36' 08" W	Cinders and local welded spatter	158.3
Colton #158	Sec. 33, 34, T25N R7E, 35° 30' 32" N, 111° 38' 0" W	Cinders and local welded spatter	83.7
Colton #57	Sec. 31,32 T25N R7E 35° 30' 00" N 111° 41' 30" W	Cinders and local welded spatter	218.9
Colton #156	Sec. 33, T25N, R7E 35° 29' 47" N 111° 39' 22" W	tuff of fine grained matrix that is overlain by cinders	117.7
unnamed	Sec. 4, T24N, R7E 35° 29' 25" N 111° 39' 53" W	cinders and scattered weld spatter	29.9
unnamed	Sec. 34, T25N, R7E 35° 29' 52" N 111° 38' 09" W	small cone - not visited	0.2

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
Maverick Butte	Sec. 3, T24N, R6E 35° 29' 27" N 111° 44' 27" W	Red cinders and bombs nearly complete layer of large bombs and welded spatter at top	19.2
Colton #58	Sec. 8, T24N, R7E 35° 38' 50" N 111° 40' 23" W	Cinders with scattered welded spatter	164.5
unnamed	Sec. 8, T24N, R7E 35° 28' 24" N 111° 40' 55" W	Red cinders and welded spatter subjected to erosion	24.9
unnamed	Sec. 17, T24N, R7E 35° 27' 58" N 111° 40' 44" W	cone - not visited	1.6
Colton #63	Sec. 12, 13, T24N R6E, 35° 28' 10" N, 111° 42' 45" W	Small black and red cinders; northeast rim is covered by basalt and welded spatter; a 50-75 foot thick layer of basalt or massive welded spatter occurs on southwest rim of crater lake basin	213.2
Colton #64	Sec. 14, T24N, R6E 35° 27' 50" N 111° 43' 16" W	Small black cinders, southern rim is capped by large locks, erosion on eastern side reveals possible tuff cone beneath cinders	109.1
unnamed	Sec. 14, T24N, R6E 35° 28' 08" N 111° 43' 55" W	Small cinder cone - not visited	0.37
Colton #60	Sec. 28, T24N, R7E 35° 26' 22" N 111° 39' 50" W	Red cinders and spatter; west side looks to have ledges of basalt or welded spatter inter-bedded with cinders	34.3
Colton #61	Sec. 29, T24N, R7E 35° 26' N 111° 40' 22" W	Red cinders of Woodhouse age	22.2

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
Colton #76	Sec. 5, T23N, R7E 35° 24" 45" N. 111° 40' 05" W	Red cinders and spatter. In U.S. Forest Service pit on east side, spatter is poorly welded. At the top is a thin layer of strongly welded spatter and basalt. Black cinders have been excavated from the south flank of the cone.	5.0
Colton #65	Sec. 24, T24N, R6E 35° 26' 40" N 111° 42' 50 " W	Small red and black cinders and local spatter. At the summit and ridges that trend northward, massive welded spatter and basalt occurs. A lava flow seems to emerge on one such ridge.	336.6
Colton #67	Sec. 25, T24N, R6E 35° 25' 53"N 111° 42' 32"W	Small red and black cinders and local welded spatter. The top and west side ridges are capped by massive welded spatter.	44.8
unnamed	Sec. 36, T24N, R6E 35° 25' 13"N 111° 42' 25" W	Red and black cinders and local welded spatter	5.8
Saddle Mtn. Colton #66	Sec. 26, T24N, R6E 35° 26' 15" N 111° 43' W	Small black cinders, near top red cinders and local welded spatter occur	316.3
unnamed	Sec. 27, T24N, R6E 35° 25' 40" N 111° 44' 35" N	Cinder pit in westmost hill reveals small black cinders	1.8
unnamed	Sec. 27, T24N, R6E 35° 25' 40" N 111° 44' 54W	By association with other cinders are assumed to be small black cinders	1.29

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
unnamed	Sec. 27, T24N. R6E 35° 26' 20" N 111° 44' 40" W	By association with Saddle Mtn. the presence of small black cinders is assumed	2.57
unnamed	Sec. 22, T24N, R6E 35° 26' 48" N 111° 44' 30"W	Red cinders and spatter	2.45
Colton #68	Sec. 35, T24N, R6E 35° 25' 25" N 111° 43' 20" W	Small red and black cinders and local welded spatter	21.9
Walker Lake Colton #69	Sec. 11, T23N, R6E 35° 23' 35" N 111° 43' 55" W	Red cinders and local welded spatter. South rim capped by massive welded spatter. North rim has large bombs and spatter. Lake sediments in center are interbedded with small black cinders. The source of these cinders is probably Saddle Mtn.	92.5
Colton #249	Sec. 6, T24N, R6E 35° 29' 48" N 111° 48' 17" W	Red cinders, welded spatter and bombs. On the north end of the cinder cone there occurs a 15-20' thick layer of massive welded spatter. On the south end, cinders suitable for road surfacing have been obtained by the U.S. Forest Service.	12.1
unnamed	Sec. 1, T24N, R5E 35° 29' 43" N 111° 48' 42" W	Roadcut on southwest side indicates presence of red cinders and spatter	0.29
unnamed	Sec. 22, T24N, R6E 35° 26' 37" N 111° 45' 06" W	Small cone - not visited	0.20

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
unnamed	Sec. 27, 28, 33, T24N, R6E 35° 25' 48" N 111° 45' 17" W	Ridge of cinders exposed by a roadcut on southwest end where small red and black cinders occur.	2.06
unnamed	Sec. 34, T24N, R6E 35° 25' 28" N 111° 45' 10" W	Assumed to be small red and black cinders associated cones	0.57
Colton #106	Sec. 29, T24N, R6E 35° 26' 15" N 111° 46' 35" W	Red cinders and spatter The uppermost 150' contains abundant large bombs and spatter	29.0
Horseshoe Hill Colton #107	Sec. 29,30,31, R6E 32, T24N, R63 35° 25' 35" N 111° 47' 20" W	Most of this cinder ring is red cinders. A massive basalt cap about 50-60' thick occurs on the northwest rim. Adjacent vents to the northwest (Sec. 30) are capped by large bombs. At the extreme north side intersecting dikes 2-3' wide occur and are continuous with lava flows that cover the northern side of the cinder cone	78.4
Crater Lake Colton #257	Sec. 36, T24N, R5E 35° 25' 02" N 111° 48' 40" W	Red and black cinders and scattered bombs. Northern crater rim has a massive dike-like body of welded spatter	37.9
unnamed	Sec. 4, T23N, R6E 35° 24' 21" N 111° 46' 02" W	This vent is not a cinder cone, but is composed of angular blocks of andesite less than one foot across.	1.5
unnamed	Sec. 6, T23N, R6E 35° 24' 02" N 111° 48' 20" W	weathered, red cinders. bombs occur at the top	1.2

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
unnamed	Sec. 12,13,T23N R5E 35° 23' 05" N 111° 48' 30" W	Scattered spatter in red cinders. Most of this cone is not on U.S. Forest Service land	1.25
unnamed	Sec. 7, 8, 17, 18, T23N, R6E, 35° 23' N 111° 47' 10" W	Red cinders and interbedded with welded spatter. A U.S. Forest Service cinder operation shows that welded spatter constitutes a nearly continuous layer. The large part of the vent to the west is capped by 40' of welded spatter and large bombs.	5.6
Hochderffer Hills	Sec. 22, T23N, R6E	Cinder pits on private land exist here - inspection of them was not accomplished.	
Fern Mountain Colton #73	Sec. 27, T23N, R6E 35° 20' 56" N 111° 43' 08" W	Bottom is red cinders and blocks. Top 40' is a basalt flow, beneath which is 80-100 feet of massive welded spatter. Probably half of volume is actually cinders.	24.4
Colton #104	Sec. 34, T23N, R6E 35° 19' 48" N 111° 44' 30" W	Red cinders, spatter and bombs that are weathered. Overlain on north by basalt flows. All on private land.	5.13
Colton #71	Sec. 21, 22, T23N R6E, 35° 21' 47" N, 111° 45' 17" W	Red weathered cinders covered with basalt talus. Talus is from a 30 foot thick basalt flow that caps the northern side of the cone.	19.0

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
Colton #71	Sec. 21, T23N, R6E 35° 21' 34" N 111° 45' 47" W	Red cinders overlain by a hard, lithic tuff. Tuff seems to be welded together	25.1
Colton #108	Sec. 19, T23N, R6E 35° 21' 57" N 111° 48' W	Cinders; capped by 50-100' of large bombs and welded spatter	48.7
unnamed	Sec. 24, T23N, R5E 35° 22' 05" N 111° 48' 25" W	Red, weathered cinders that occur on the flanks of ridges that are dikes or lava flows. This cone has experienced significant erosion.	1.53
Antelope Hill Colton #251	Sec. 22, 23, T23N, R5E 35° 21' 38" N 111° 50' 35" W	Double cone is red and black cinders and local welded spatter. It is half on Coconino and half on Kaibab National Forest	66.2
Wild Bill Hill Colton #210	Sec. 34, T23N, R5E 35° 19' 30" N 111° 50' 55" W	Tuff cone like Red Mtn. that is slightly eroded on its north side. It is composed of breccia of basalt fragments (1-6" in size) and cinders set in a fine-grained tuff matrix. The breccia is well indurated and could not be worked without blasting. The southern slope is capped by a 20 foot thick basalt flow	80.1
Crater Lake Colton #74	Sec. 4, T22N, R6E 35° 19' 15" N 111° 45' 55"	Red cinders and spatter. Numerous large bombs occur on the north rim. A basalt flow crops out on the southeastern rim.	17.3

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
unnamed	Sec. 33, T23N, R6E 35° 20' 08" N 111° 45' 30" W	Red, weathered cinders that surround two dikes at nearly right angles to each other. Much of the cone is eroded.	2.5
Walker Hill Colton #365	Sec. 22, T22N, R5E 35° 16' 47" N 111° 50' 50" W	Red cinders in which abundant small bombs occur near the top	27.3
unnamed	Sec. 21, T22N, R6E 35° 16' 40" N 111° 45' 30" W	Red welded spatter and large bombs and is capped by 4 foot of basalt flow rock	0.98
unnamed	Sec. 21, T22N, R6E 35° 16' 27" N 111° 46' W	Red cinders, small bombs and welded spatter. Cinder pit occurs at west end of this cinder ridge	1.5
unnamed	Sec. 17, 20, T22N, R6E 35° 16' 56" N 111° 46' 33" W	small ridge of small black cinders, probably related to Wing Mtn. Cinder pit in north end indicates only scattered small bombs.	1.9
unnamed	Sec. 20, T22N, R6E 35° 16' 20" N 111° 46' 30" W	Small ridge of small black cinders related Wing Mtn. Cinder pit in east side.	4.3
Wing Mtn. Colton #75	Sec. 20, T22N, R6E 35° 16' 17" N 111° 47' 05" W	Small black cinders	255.3
unnamed	Sec. 30, T22N, R6E 35° 15' 48" N 111° 47' 54" W	Cinders and welded spatter. A dike occurs on southwest side. A small basalt flow caps the hill	1.1
Colton #241	Sec. 30, 31, T22N, R6E 35° 15' 12" N 111° 47' 22" W	Inaccessible but aerial reconnaissance indicates that two dikes of massive basalt or welded spatter occur at the summit. Otherwise composed of red cinders and welded spatter.	26.3

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
Colton #240 Riordan Cinder Pit	Sec. 15, T21N, R6E 35° 12' 13" N 111° 44' 57" W	Red and black cinders and spatter. At top large bombs and welded spatter occur. In the cinder pit on the west side, a zone of black welded cinders occurs.	14.9
unnamed	Sec. 28, T21N, R6E 35° 10' 32" N 111° 46' 14" W	Small cone of red cinders and spatter. Partly on Navajo Army Depot	1.1
A-1 Mtn. Colton #19	Sec. 2, T21N, R6E 35° 14' 07" N 111° 44' W	Red and black cinders and spatter. Southern crest has abundant large bombs, welded spatter and massive flow rock	179.9
unnamed	Sec. 35, T22N, R6E 35° 14' 22" N 111° 43' 22" W	Black and red cinders; no bombs	10.1
unnamed	Sec. 1, T21N, R6E 35° 14' 13" N 111° 43' 04" W	Red welded spatter and bombs	0.68
unnamed	Sec. 36, T22N, R6E 35° 14' 22" N 111° 42' 57" W	Red welded spatter and bombs	0.12
Colton #244	Sec. 22, T21N, R6E 35° 10' 03" N 111° 43' 20" W	Red and black cinders, spatter and bombs. On land of the U.S. Naval Observatory	14.8
Colton #105 Dry Lake Crater	Sec. 25, T21N, R6E 35° 10' 10" N 111° 43" W	Numerous cinder pits which show large variety of cinders. Mainly black and red cinders, bombs with local large bombs and welded spatter.	127.5
unnamed	Sec. 11, T20N, R6E 35° 07' 37" N 111° 43' 27" W	Red cinders, bombs and spatter	2.9

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
unnamed	Sec. 6, T20N, R6E 35° 08' 56" N 111° 48' 32" W	Large red cinders and welded spatter. Partly on the Navajo Army Depot	1.1
Sliker Hill Colton #383	Sec. 2, T20N, R5E 35° 08' 25" N 111° 50' 32" W	Red, weathered cinders exposed in upper 15 feet of this hill. Abundant bombs and welded spatter occur at the top. Two dikes 20-50 feet thick cut the cinders	5.4
unnamed	Sec. 8, T20N, R6E 35° 07' 52" N 111° 47' 25" W	Small ridge of red cinders and welded spatter. Top is capped by lava. Most of cinders are not in U.S. Forest Service land	0.4
LeBarron Hill	Sec. 8, T20N, R6E 35° 07' 30" N 111° 46' 57" W	Red weathered cinders few blocks and welded spatter near top. Some soil cover	9.8
unnamed	Sec. 9, T20N, R6E 35° 07' 30" N 111° 46' W	Ridge of cinders that has a 20' dike of basalt in its center. Cinders are red and weathered, suggesting erosion.	1.5
unnamed	Sec. 14, T20N, R6E 35° 07' 03" N 111° 43' 53" W	Red and black cinders and bombs	18.4
unnamed	Sec. 26, T20N, R6E 35° 05' 05" N 111° 44' 08" W	Red and black cinders and bombs	1.67
unnamed	Sec. 20, T20N, R6E 35° 06' 15" N 111° 46' 36" W	Red cinders, spatter and bombs; capped by 18 feet of basalt	0.98
unnamed	Sec. 25, T20N. R5E 35° 05' 05" N 111° 49' 07" W	Small red cinders and spatter mixed with white fragments of Kaibab Limestone; cinder pit on north side	0.49

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
Dutton Hill Colton #382	Sec. 13, T20N, R5E 35° 07' 07" N 111° 49' 32" W	Top 200 feet contains red weathered cinders and bombs. Uppermost 30 feet is a basalt flow. Two dikes three feet wide occur in the cinders.	3.11
unnamed	Sec. 26, T20N, R5E 35° 05' 22" N 111° 50' 35" W	Red cinders, spatter and bombs cut by a dike 20 feet wide	1.05
unnamed	Sec. 26, T20N, R5E 35° 04' 52" N 111° 50' 30" W	Red cinders, bombs and spatter cut by a small dike that feeds a basalt flow from the top towards the south	0.91
unnamed	Sec. 27, T20N, R5E 35° 05' 03" N 111° 50' 47" W	Red cinders, bombs and spatter. Basalt emerged near the top and flowed down the south side	0.63
unnamed	Sec. 27, T20N, R5E 35° 04' 57" N 111° 51' 12" W	Red cinders, bombs and spatter capped by 15 feet of basalt	4.65
Mooney Mtn. Colton #381	Sec. 6, T20N, R5E 35° 08' 30" N 111° 54' 18" W	not examined carefully red cinders present	57.4
unnamed	Sec. 9, T20N, R4E 35° 07' 55" N 111° 59' 02" W	not visited	0.87
unnamed	Sec. 9, T20N, R4E 35° 07' 34" N 111° 58' 24" W	not visited	3.9
unnamed	Sec. 10, T20N, R4E 35° 07' 14" N 111° 57' 10" W	not visited	5.72
unnamed	Sec. 13, 14 T20N, R4E 35° 06' 55" N 111° 55' 57" W	not visited	2.5

Name of Cone	Location	Description	Volume of Cone (millions of cu. yards)
Red Hill	Sec. 31, T20N, R5E 35 04' N 111 53' 28" W	Large red cinders, bombs and spatter. Local welded spatter and lava. A lava flow emerged from the top and flowed southeast	37.4
unnamed	Sec. 7, T20N, R5E 35 02' 18" N 111 54' 44" W	Red cinders, bombs and spatter. Local welded spatter. A lava flow emerged at the top and flowed toward the southeast	2.6

APPENDIX B

ENGINEERING DATA ON ARIZONA HIGHWAY DEPARTMENT BORROW PIT LOCATIONS

The following data sheets include the locations and information from engineering tests performed by the Arizona Highway Department on materials in borrow pits which are designated as use permits from the U.S. Forest Service on the Coconino National Forest. The number of each designated borrow pit is keyed to its location on the Map of Borrow Pit Locations. The designated sites are arranged in the Data Sheets according to the District in which they are located.

These sites have not been evaluated in the field, due to limited time and assistance. Field examination will be necessary before an adequate evaluation of the rock type and current operational status of each site can be made. Copies of the Highway Department records from which this data was derived are on file in the Supervisors Office, Coconino National Forest, Flagstaff, Arizona.

The following abbreviations used in the data sheets are taken directly from the Highway Department engineering reports, except that we have included definitions herein. We have not attempted to consolidate overlaps or duplications of terminology or otherwise alter the classification of materials.

Definitions of Abbreviations used in Data Sheets

Material:

AB = aggregate base
ABC = aggregate base course
AG = aggregate
B = borrow
C = clay
CTB = cement treated base
LS = limestone
MA = mineral aggregate
S = silt
SM = select material
SS = subgrade seal
SUR = surfacing

Test data:

H(12) = core hole (number of holes/site)
SA = sieve analysis available

We have not included information on cinder pit operations by the A.T. and S. F. Railroad because they are on private land and have been concentrated in two large operations, one at Bellmont and the other at Winona.

The use of Forest Service land by private contractors is not included because the records for these operations are already in possession of the Supervisors Office and the operations are closely supervised by that office.

Beaver District (D-1)

Prepared By		
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Pit No.	Location Sec.	T	N/R	E	Rock Unit	Material	Date Designated	Area	Volume X1000 yd³		Test H=drill hole SA=sieve ANAL
5780 HD	NE	34	16	6		SM, MA AG	8/58	1000X600'		?	H(34), SA
5782 HD	SE	10	16	7		SM, AB, MA, AG.	8/56	400X800'			H(16), SA
5783 HD	SE	10	16	7		AG	?	?	13	+	H(12), SA
6384 HD	NW	12	15	5		B, Sg.	10/60	600X600'	25	+	H(9), SA
6385 HD	NW	1	15	5		B, SM, MA, AG	11/60	600X540'	25	+	H(8), SA
6386 HD	Line Between	25+30	16	5+6		SM, MA, ABC, AG, B	7/61	800X2000'			H(63), SA
7585 HD	Line Between	8+9	15	6		B	1/67	200X1000'	10	+	H(5), SA
8270 HD	Line Between	17+20	16	7		B	11/70	390X480'		?	H(13), SA

NO. 54-24-2 GREEN TINT NO. 58-252 BUFF RITE ACROSS MADE IN U.S.A.

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Elden District (D-2)

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Pit No.	Location Sec.	T	N	R	E	Rock Unit	Material	Date Designated	Area	Volume x1000 yd³	Test μ=drillhole SA=Sieve Anal.	Used	
212 HD	SW	33	22	7			AG	9/45	ND		H(3), SA		USFS Red pin
766 HD	NW	9	21	8			AG, T	7/43	ND		H(3), SA		
767 HD	NE	10	21	8			AG, B	12/69	1500 X 700'	33	H(27), SA		
769 HD	Line Between	2+3	20	10			AG, AB, B	6/65	1000 X 1600'		H(74), SA		
770 HD	NE	23	21	9		cinders	B, SM, ABC, MA	2/53	ND		H(13), SA		
771 HD	SW	19	21	10			B	3/53	1000 X 1000' 45.08 Ac.	16 +	H(10), SA	7/68	
2606 HD	NE	9	21	8		cinders	ABC, SM	8/43	?		H(8), SA		
5327 HD	NE	5	21	8		cinders	MA, AG,	11/56	250 X 250'	75 +	H(3), SA		
5667 HD	NE	6	21	8			B, AG	11/57	300 X 600'	53 +	H(5), SA		
5669 HD	NW	29	22	8		sandstone	SS, AG.	2/58	800 X 1000'		H(17), SA		
5671 HD	Lines Between	18, 17, 19, 20	22	8			B	11/57	700 X 400'	50 +	H(7), SA		
5672 HD	SW	17	22	8			B	11/57	600 X 400'	22 +	H(6), SA		Approx. 22,000 c.yd. SHRUNK 15%
5673 HD	SW	8	22	8			B	2/58	200 X 700'	30 +	H(9), SA		Approx. 30,000 c.yd. SHRUNK 15%
5674 HD	SW	5	22	8			B	2/58	200 X 900'	25 +	H(12), SA		
5676 HD	NE	32	23	8			B	?	ND	15 +	H(5), SA		SHRUNK 15%
5677 HD	SW	29	23	8			B	2/58	400 X 400'	130 +	H(8), SA		
5863 HD	NE	19	24	8			SM, MA, AG	12/58	700 X 600'	65 +	H(22), SA		
6091 HD	NW	3	20	10			AG, SM, AB, MA	8/59	1300 X 400'	40 +	H(21), SA		
6233 HD	NE	10	21	9			MA, ABC, SM, B, AB, AG	4/60	300 X 600'	80 +	H(12), SA		Borrow - 20,000 c.yd. other - 60,000 c.yd.
6234 HD	Line Between	34+35	22	9			B	4/60	800 X 900'	100 +	H(14), SA		

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Elden District (D-2) Page 2

Prepared By	Initials	Date
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Pit No.	Location	Sec	T	N	R	E	Rock Unit	Material	Date Designated	Area	Volume (1000 yd³)	Test (H-hardness, SA-sodium sulfate soundness)												
6235 HD	SW	26	22	9				B	4/60	100 X 400'	20 +	H (4), SA												
6236 HD	SW	25	22	9				MA, ABC, SM, B, AG	4/60	600 X 300'	?	H(7), SA												
6237 HD	Line Between	25+30	22	9+10				B	4/60	100 X 1200'	40 +	H(8), SA												
6238 HD	SW	19	22	10				B, SM, AG	9/60	300 X 900'	100 +	H (3), SA												
6239 HD	Line Between	19+30	22	10				SM, B, AG	3/60	300 X 900'	70 +	H (18), SA												
6370 HD	Line Between	21+16	21	9				B	8/60	200 X 1200'	44 +	H (6), SA												
6371 HD	Line Between	24+19	21	9+10				B, AG	9/60	2200 X 500'	125 +	H (20), SA												
6869 HD	Line Between	18+17	21	9				B	8/62	400 X 400'	37 +	H(4), SA												
7137 HD	SW	15	21	9				Ss, SM, AG	7/60	1100 X 100'		H (1), SA												
7308 HD	NW	29	22	9				B, Ss, SM, AB AG	?	360 X 325'		H(34), SA												
7454 HD	NW	20	21	9				B, SM, CTL, AG	6/67	1200 X 1200'	85 +	H(24), SA												
7619 HD	NW	8	21	8				B, AG	2/67	500 X 1000'	15 +	H(11), SA												
7626 HD	Line Between	7,8+18,17	23	8				AG	?	?	45 +	H(53), SA												
7627 HD	NE	9	23	8				MA	3/24	600 X 1000'	200 +	H(13), SA												
7680 HD	NW	15	21	9				AG	8/67	1000 X 500'	200 +	H(12), SA												
7682 HD	NE	28	21	10				AG	7/67	1000 X 1000'	300 +	H(13), SA												
7784 HD	NE	24	21	9				B	?	ND		H(3), SA												
7806 HD	Line Between	28+29	22	8				SM, AG	11/57	2100 X 700'	97 +	H(22), SA											Shrunk 10%	
7807 HD	SE	13	23	7				MA, AG	?	1200 X 200'		H(3), SA											USFS Red Pin	
7850 HD	NE	23	21	9				AG	4/68	700 X 700'		H (43), SA												
8163 HD	NE	5	21	8				B	8/69	400 X 600'	70 +	H (6), SA												

NO 58 24 3 GREEN "K" NO 58 5" SHEFFIELD RITE ACROSS MADE IN U.S.A.

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Elden District (D-2) Page 3

Prepared By	Initials	Date
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	Pit No.	Location Sec.	T	N	R	E	Rock Unit	Material	Date Designated	area		Volume X10..		Type of Material SA= Sieve Anal.	7	8	9	10	11	12	
1	8253 HD	NE	5	21	9		Basalt	AG, S, C	12/70	600	X 400	35	+	H(12), SA							1
2																					2
3																					3
4																					4
5																					5
6																					6
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FLAGSTAFF District (D-3)

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Pit No.	Location	Sec.	T N	R E	Rock Unit	Material	Date Designated	Area	Volume X1000 yd³	Test H=drill hole SA=Sieve Anal.		
205 HD	NW	32	23	6		?	7/51	?	?	H(2), SA		
206 HD	SW	17	23	6		AG, SM ABC	4/51	200X300'		H(15), SA		
207 HD	SE	19	23	6		B	7/51	500X500'		H(3), SA		
208 HD	NW	9	23	6		B	7/51	250X250'		H(4), SA		
209 HD	NW	10	23	6		B	4/51	200X225'		H(5), SA		
210 HD	SW	3	23	6		B	4/51	150X250'		H(4), SA		
213 HD	NW	32	22	7		AG	3/47	ND		H(2), SA		
214 HD	NW	15	21	6		AG, B	11/53	800X1600'		H(17), SA	FS yel. pin	
1569 HD	SE	28	24	6		AG, SM	10/53	500X500'	13 +	H(12), SA		
1570 HD	SE	28	24	6		AG, SM	5/55	300X300'		H(10), SA		
1572 HD	SW	21	24	6		B	5/55	200X400'		H(7), SA		
1573 HD	SW	21	24	6		B	4/55	200X300'	9 +	H(6), SA		
1579 HD	SW	17	24	6	cinders	B	5/55	250X400	10 +	H(7), SA		
2603 HD	NW	14	21	7		ABC, SM?	?	?		H(11), SA	"Obsolete"	
2604 HD	SE	14	21	7		"T," ABC	10/41	?		H(31), SA		
5536 HD	NE	35	21	6		AG, B, SM, AB, MA	9/58	450X450'	150 +	H(25), SA	FS yel. pin	
5571 HD	NW	5	20	7		B	8/57	400X700'	28 +	H(8), SA		
5572 HD	NE	32	21	7		B	8/57	400X500'	19 +	H(46), SA		
5570 HD	NE	8	20	7		B	8/57	400X700'	21 +	H(7), SA		
5584 HD	Line between	17&20	22	6		AG, MA	9/57	1300X1000'	100 +	H(29), SA	FS yel. pin	
5585 HD	Line between	17&18	23	6		B, MA	9/57	400X500'	85 +	H(12), SA	FS yel. Pin	

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Flagstaff District (D-3) Page 2

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	Pit No.	Location	Sec.	T	N	R	E	Rock Unit	Material	Date Designated	Area	Volume x1000 yd³	Test H=Drill hole SA=Sieve Anal.	
1	5868	HD Line Between	27+34	24		6			MA, AB, SA, AG	4/59	800 X 600'		H(18), SA	
2														
3	6471	HD NE	26	21		6			AB, AG	8/61	600 X 700'	?	H(23), SA	
4														
5	6472	HD Line Between	24+25	21		6			B	8/60	900 X 500'		H(19), SA	
6														
7	6473	HD SW	30	21		7		Cinder	AG, B	8/60	900 X 1500'	?	H(62), SA	
8														
9	6488	HD SE	23	21		7			B, AG, Ss	5/61	1400 X 1600'	145 +	H(45), SA	Subgrade Seal - 60,000 c. yd. Borrow - 85,000 c. yd.
10														
11	7023	HD Line Between	25+36	21		7			AG, B	11/64	1600 X 1600'	420 +	H(31), SA	Borrow - 50,000 c. yd.; AGGREGATE - 70,000 c. yd. FS. 2 yel. Pins
12														
13	7611	HD SE	7	21		8			AG, B, Ss, CTB	1/67	750 X 1000'	182 +	H(10), SA	Subgrade Seal - 90,000 c. yd. Borrow - 70,000 c. yd. Sub. Seal + CTB - 20,000 c. yd.
14														
15	7617	HD SE	7	21		8			AG, Ss.	2/67	500 X 750'	220 +	H(10), SA	Subgrade Seal - 20,000 c. yd. Aggregate - 200,000 c. yd.
16														
17	7625	HD SW	31	21		7		Basalt	AG	4/67	900 X 300'	?	H(9), SA	
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NO SMUDGE SHEEN-FAST NO SMEAR-SURFACE ACROSS MADE IN U.S.A.

S.E.A.M. KEUFFEL & ESSER CO. E. ZABETH, N. J. 07208 A Division of THE MEAD CORPORATION

Long Valley District (D-4)

Prepared By	Initials	Date
Approved By		

	Pit No.	Location Sec.	T	N/R	E	Rock Unit	Material	Date Designated	Area	Volume x1000 yd³		Test H-drill hole SA=Sieve Anal.
1	1568 HD	SE	27	17	9		SM	6/SB	250'x250'	N	D	H(9), SA
2												
3	7150 HD	NE	27	17	9	Cinders	SM, SS, AB, AG	?	1000'x800'	25±	F	H(26), SA
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NO 58-252 GREEN TINT NO 58-252 BLUE RITE ACROSS MADE IN U.S.A.

S.E.A.M. VERNON CO. ELIZABETH N.J. 07208 A DIVISION OF THE MEAD CORPORATION

MORMON LAKE District (D-5)

Prepared By	Initials	Date
Approved By		

Pit No.	Location	Sec	T	N R	E	Rock Unit	Material	Date Designated	Area	Volume x1000 yd³	Test (H=drill hole SA=surface)	
831 HD	SW	26	20		9		B	8/54	N D		H(10), SA	
2086 HD	NE	11	20		7		Ss	?	220 X 770'	25 +	H(8), SA	
5344 HD	SW	24	17		7		AG	10/56	600 X 300'	40 +	H(15), SA	
5345 HD	SW	11	17		7		B	1/57	200 X 1000'	?	H(13), SA	
5346 HD	SE	3	17		7		AG, B, SM	1/57	600 X 450'	40 +	H(10), SA	
5347 HD	NE	33	18		7		B	11/56	400 X 600'	?	H(9), SA	
5515 HD	NW	8	18		7		B	3/57	400 X 200'		H(3), SA	
5516 HD	NW	12+8	18		6+7	BASALT	AG, MA	?	800 X 1200'		H(38), SA	(TWO green pins mark area)
5517 HD	SE	1	18		6		B, Ss, SM	5/57	600 X 500'	30 +	H(19), SA	
5518 HD	NW	1	18		6		AG, B	?	1600 X 1600'		H(29), SA	
5562 HD	SE	25	19		6		B	6/57	500 X 1000'	200 +	H(12), SA	
5563 HD	Line Between	17+18	19		7		B	7/57	N D		H(7), SA	
5564 HD	NW	6	19		7		AG, SM, Ss	7/57	1200 X 800'	?	H(34), SA	
7022 HD	NE	6	19		7		B	6/63	400 X 400'		H(6), SA	
7063 HD	SW	9	18		7		B	8/63	200 X 200'		H(4), SA	
7064 HD	NW	17	20		7		B, AG	8/63	200 X 200'	80 +	H(2), SA	BORROW - 5,000 c.yd. AGGREGATE - 75,000 c.yd.
7100 HD	NE	7	18		9		B	10/63	1000 X 800'		H(9), SA	
7101 HD	SW	27	18		8		AG, MA, AB	10/63	500 X 400'	90 +	H(13), SA	
7102 HD	NW	33	18		9		B	?	200 X 800'		H(4), SA	
7311 HD	Line Between	18+17	20		7		B, AG	6/65	600 X 800'		H(17), SA	
7354 HD	Line Between	24+25	19		6		B	5/65	800 X 800'		H(8), SA	

WATERMAN GRAPH PAT. NO. 58,412 "RIFF-RITE ACROSS" MADE IN U.S.A.

S E & M VERNON TO ELIZABETH N.J. 07208 A DIVISION OF THE MEAD CORPORATION

MORMON LAKE District (D-5) Page 2

	Initials	Date
Prepared By		
Approved By		

Pit NO.	Location Sec	T	N	R	E	Rock Unit	Material	Date designated	Area	Volume X1000 yd³	Test H=drill hole SA=surface analysis
7389 HD	SW	29	20		7		B.	6/65	300X300'		H(6), SA
7393 HD	SE	12	18		6		B	?	?	67 +	H(9), SA
7535 HD	NE	32	18		9		B	?	?	2 +	H(4), SA
7607 HD	SE	8	20		7		AG,	1/67	500X1000'		H(13), SA
7679 HD	NE	34	18		9		AG	12/66	300X500'		H(4), SA
7790 HD	NE	22	18		7		B	4/57	500X700'		H(7), SA
8082 HD	SW	6	19		7		AG	10/68	1000X800'		H(18), SA
8111 HD	SE	24	20		7	Limestone	Ls.	?	450X350'	50 +	H(7), SA
8117 HD	NE	35	17		7		AG.	6/69	1200X600'	200 +	H(22), SA

NO 54 343 GREEN PNT NO 58-242 BURF WITE ACROSS* MADE IN U S A

S E & M VERNON CO ELIZABETH N J 07208 A DIVISION OF THE MEAD CORPORATION

SEDONA District (D-6)

Prepared By	Init's	Date
Approved By		

Pit No.	Location	Sec.	T	N	R	E	Rock Unit	Material	Date Designated	Area	Volume X1000 yd³	Test H=dr.Whole SA=Sieve Anal.
612 HD	Line Between	25+26	17		5			MA, ABC, SM, AB	3/48	175X500'		H(10), SA
1779 HD	NW	17	18		6			SUF, S, C	8/52	N D		H(3), SA
2442 HD	NW	19	17		5			MA	10/47	N D		H(6), SA
5189 HD	NE	25	16		5			AG, SM, ABC, Mx	4/56	250X1100'	7 +	H(14), SA
7681 HD	SW	17	17		5			AG.	7/67	400X1600'	20 +	H(34), SA
7728 HD	NW	1	15		3			B	11/67	300X400'	20 +	H(4), SA

NO. 1442 GREEN TINT NO. 56-243 BUFF RITE ACROSS MADE IN U.S.A.

S.E. & M. VERNON CO. ELIZABETH, N.J. 07208 A DIVISION OF THE MEAD CORPORATION

Blue Ridge District (D-7)

	Initials	Date
Prepared By		
Approved By		

	Pit No	Location Sec.	T	N R	E	Rock Unit	Material	Date Designated	Area	Volume X1000 yd³	Test H: dry lab SA: sieve							
1	7658 HD	NE	4	15	12		B	?	?	49 +	H(4), SA							1
2																		2
3	8027 HD	SW	4	15	12		AG	7/68	600X900'	128 +	H(25), SA	AGGREGATE - 35,000 c. yd. BORROW -						3
4												93,800 c. yd.						4
5	8158 HD	SE	26	15	9		AG	1/70	1000X500	100	H(8), SA							5
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NO 58-2413 GREEN TINT NO 58-242 BUFF RITE ACROSS" MADE IN U.S.A.

SEE M KEPHART CO ELIZABETH N J 07206 A Division of THE MEAD CORPORATION